USE OF INTERACTIVE METHODS IN EXPRESSING MOTION EQUATIONS IN DIFFERENT COORDINATE SYSTEMS

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Abstract. *In this work, students were studied how to solve the problems that arise when expressing the equations of motion in different coordinate systems using interactive methods. Connections between the coordinate system, the radius vector, the velocity vector and the acceleration vector can be cited as concepts that are important in mastering all topics in theoretical mechanics. Because all the knowledge that needs to be mastered goes back to the above concepts. In theoretical mechanics, the interactive methods used to create a complete knowledge of the coordinate system, the trajectory of a material point, and the expression of its speed and acceleration in coordinates are highlighted.*
Keywords: *coordinate system, radius vector, velocity vector, acceleration vector, equation of motion, "metreshk*a method".

It is not a secret to anyone that today a desired science is rapidly developing. If we look closely at the voluntary sector, it is possible to notice new changes. This, in turn, creates the need to ensure that our young people receive education in accordance with the rapid changes in development. It is necessary for our youth to understand that great knowledge lies at the foundation of achievements, especially in concrete and natural sciences, and educators should help in this regard. If we look at the achievements in physics from this point of view, it is based on strong fundamental knowledge. We can show the theoretical courses of physics as a course that is difficult to master. It is no exaggeration to say that only if the theoretical courses are well mastered, the essence of physics will be fully understood and the achievements of the science will be reached. In particular, as a result of the information obtained in the course of theoretical mechanics, they gain knowledge about the theoretical foundations of important phenomena such as the law of conservation of energy, the law of conservation of momentum, the equations of vibrations, the collision of particles, and decay. It is difficult to master the next theoretical courses of physics without mastering these concepts perfectly. This, in turn, leads to a decrease in the rate of absorption and has a negative impact on the issue of providing competitive personnel. That is why it is important to increase the rate of mastery of theoretical mechanics by students.

Connections between the coordinate system, the radius vector, the velocity vector and the acceleration vector can be cited as concepts that are important in mastering all topics in theoretical mechanics. Because all the knowledge that needs to be mastered goes back to the above concepts. In order to create deep knowledge in theoretical mechanics, it is necessary to create complete knowledge about the coordinate system, expressing the trajectory, speed and acceleration of a material point in different coordinate systems. Students face certain difficulties in mastering these concepts. As a reason for this, we can cite the fact that students used only the Cartesian coordinate system until this topic. But there are cases where it is inconvenient to express its equation of motion in the Cartesian coordinate system. In addition, it is necessary to refer to the knowledge related to mathematics and vectors when expressing the connections between coordinates, radius vector, velocity vector and acceleration vector. In such cases, it is appropriate to use methods that match the topic during the lesson to increase the mastery rate.

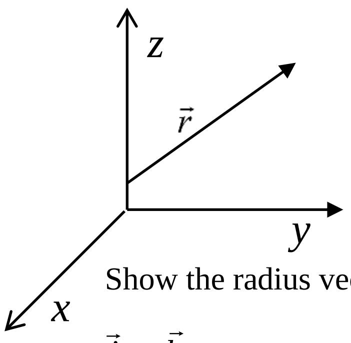
Any movement in nature is relative. It is necessary to choose a coordinate system to represent the movement of the body. Otherwise, whether the point is moving or the observer remains abstract. Therefore, the appropriate coordinate system is selected for movements with different trajectories.

The following coordinate systems are addressed in the theoretical mechanics course: Cartesian coordinate system, cylindrical coordinate system, spherical coordinate system, and polar coordinate system. The coordinates in all coordinate systems can be represented by Cartesian coordinates, that is, the coordinate systems are related to each other. The simplest and most convenient system known to us is the Cartesian coordinate system.

The laws of motion of a material point in the Cartesian coordinate system are as follows

$$x = x(t), \quad y = y(t), \quad z = z(t) \tag{1}$$

The vector directed from the coordinate origin to the material point is called a radius vector. The radius vector expressed by coordinates is written in the following form.



Show the radius vector in the picture

$$\vec{r} = x\vec{i} + y\vec{j} + z\vec{k} \tag{2}$$

Also, the complete differentials of this radius-vector with respect to time give the velocity and acceleration vectors of the point

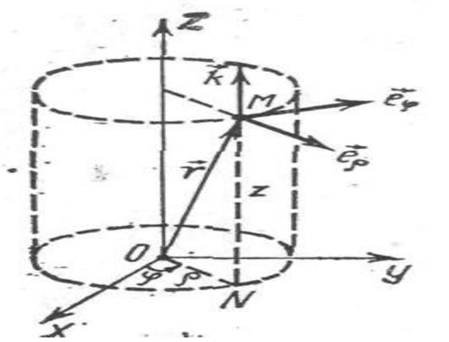
$$\vec{v} = \dot{\vec{r}} = \dot{x}\vec{i} + \dot{y}\vec{j} + \dot{z}\vec{k} \tag{3}$$

$$\vec{a} = \dot{\vec{v}} = \ddot{\vec{r}} = \ddot{x}\vec{i} + \ddot{y}\vec{j} + \ddot{z}\vec{k} \tag{4}$$

Projections of velocity and acceleration vectors on axes can be written in the following form

$$v_x = \dot{x}, \quad v_y = \dot{y}, \quad v_z = \dot{z}; \qquad a_x = \dot{v}_x = \ddot{x}, \quad a_y = \dot{v}_y = \ddot{y}, \qquad a_z = \dot{v}_z = \ddot{z} \qquad (5).$$

There are processes for which it is inconvenient to use the Cartesian coordinate system in the formulation of the equations of motion. For example: changes in liquid crystals, changes in biological fluids in a centrifuge are convenient to see in cylindrical coordinates.



In the cylindrical coordinate system, the position of point M is determined by the coordinates ρ, φ, Z . Laws of motion of a point

$$\rho = \rho(t), \quad \varphi = \varphi(t), \quad z = z(t) \qquad (6)$$

will be in appearances.

Cartesian coordinates can be written in cylindrical coordinates as follows.

$$x = \rho\cos\varphi, \quad y = \rho\sin\varphi, \quad z = z \qquad (7)$$

$$\vec{r} = \rho \cdot \vec{e}_\rho + z\vec{k} = x\vec{i} + y\vec{j} + z\vec{k} \qquad (8)$$

To find the connection between $\vec{e}_\rho, \vec{e}_\varphi$ the coordinates of the cylindrical coordinate system and $\vec{i}, \vec{j}$ the Cartesian coordinates we mutually equate expressions (8) in both $\vec{r}$ radius-vector systems and, taking into account (7), we get the following connections:

$$\vec{r} = \rho \cdot \vec{e}_\rho + z\vec{k} = x\vec{i} + y\vec{j} + z\vec{k} = \cos\varphi\vec{\imath} + \sin\varphi\vec{\jmath} + z\vec{k} \quad (9)$$

What is this

$$\vec{e}_\rho = \vec{i}\cos\varphi + \vec{j}\sin\varphi, \quad \vec{e}_\varphi = \frac{d\vec{e}_\rho}{d\varphi} = -\vec{i}\sin\varphi + \vec{j}\cos\varphi \qquad (10)$$

we will have results.

To convert from radius vector to speed, it is necessary to take derivative of radius vector with respect to time

$$\vec{v} = \dot{\vec{r}} = \dot{\rho}\vec{e}_\rho + \rho\dot{\vec{e}}_\rho + \dot{z}\vec{k} = \dot{\rho}\vec{e}_\rho + \rho\left(\frac{d(\cos\varphi\vec{\imath} + \sin\varphi\vec{\jmath})}{dt}\right) + \dot{z}\vec{k} \qquad (11)$$

It appears. This is where most students make a mistake. (10) is derived from the simple function. But (11) is the derivative of a complex function. In this case, using the matreshka method gives its effective result. Here φ the function also changes according to t. In this case, the following is appropriate $\vec{e}_\rho(\varphi(t))$. We use the "Matryushka" method to calculate the product. This method is as follows: $F(q(k(r(x)))'_x$ if we take the derivative of the function with respect to x $F'_q \times q'_k \times k'_r \times r'_x$ looks like. By opening each parenthesis, the derivative is obtained from the previous function with respect to the visible function. It reminds me of a Russian matryoshka. Let's number the matryoshka dolls in Figure 1 consecutively as 1, the smallest one. We apply to the derivation problem as follows: derivative of matryoshka 5 by matryoshka 4, derivative of matryoshka 4 by matryoshka 3, derivative of matryoshka 3 by matryoshka 2 and derivative of matryoshka 2 by matryoshka 1 . It is similar to the derivative of the complex function above. $\vec{e}_\rho(\varphi(t))$ it is necessary to take a derivative from a function that looks like.

If we use this method, we will have the following.

$$\dot{\vec{e}}_\rho = \dot{\varphi}(-\vec{i}\sin\varphi + \vec{j}\cos\varphi) = \dot{\varphi}\cdot\vec{e}_\varphi, \qquad \dot{\vec{e}}_\varphi = -\dot{\varphi}(\vec{i}\cos\varphi + \vec{j}\sin\varphi) = -\dot{\varphi}\cdot\vec{e}_\rho \qquad \dot{\vec{e}}_\rho = \dot{\varphi}\cdot\vec{e}_\varphi, \qquad \dot{\vec{e}}_\varphi = -\dot{\varphi}\cdot\vec{e}_\rho \qquad (12)$$

We can determine the velocity and acceleration vectors if we take into account the equations (12) in the time derivatives of the radius vector of the point (11).

$$\vec{v} = \dot{\rho}\vec{e}_\rho + \rho\dot{\varphi}\vec{e}_\varphi + \dot{z}\vec{k} \qquad (13)$$

we get the expression of acceleration in the form.

Derivatives of this form are formed both in spherical coordinates and in polar coordinates. Explaining to students the derivative of a complex function in the "matryoshka" method increases the mastery rate. In addition, the connection between the trajectory, speed, and acceleration of a material point in all coordinate systems is important. Because Lagrange's formalism, which is one of the most basic concepts of the course of theoretical mechanics, and the connection between the radius vector, speed and acceleration in oscillating movements are of great importance. Therefore, it is necessary to create deep knowledge in students about this connection. It is appropriate to use the "matryoshka" method.

In the first case, it is enough to show that the time derivative operation is used to move from the outer matreshka to the inner matreshka.

$$\dot{\vec{x}} = \vec{v}, \qquad \dot{\vec{v}} = \vec{a}, \qquad \ddot{\vec{x}} = \vec{a} \qquad (14)$$

To solve each layer, it is enough to take the first-order time derivative. If there are two shells, it is enough to take the second-order time derivative.

Between the radius vector and the acceleration, the shell takes the second order derivative with respect to time, so to go from the radius vector to the acceleration.

Now, in order to further strengthen this concept in students, it is enough to explain that it is enough to integrate over time to move from the inner matryoshka to the outer matryoshka. The above drawing can be used to develop skills in students.

The topics of the course of theoretical mechanics specified in the practical training are given to strengthen the knowledge gained in the lecture. It is not an exaggeration to say that the mastery of the subject will be high only if the students achieve a high mastery rate on the subject set for practical training. Based on the given equations of the motion of a point, the problems of constructing the laws of its motion along the trajectory will be the basis for students to get deeper into the essence of the connections between the equation of motion, radius vector, speed and acceleration. The following examples can be used to solve the problems related to the above conditions:

Based on the given $x = acos^2 5t \qquad y = asin^2 5t$ equations, formulate the law of movement of the point along the trajectory. Let the following problem be given. To solve this problem, it is necessary to take the time derivative from the previously given equations. A similar problem may be given as follows:

Based on the given $x = \cos 5t^2$ $y = \sin 5t^2$ equations, construct the law of movement of the point along the trajectory. To find the law of movement along the trajectory, it is necessary to find the components of the speed on the axes, and then to find the expression of the total speed and differentiate it with respect to time. From the equations of motion of a point on the X and Y axes, it is necessary to derive the time derivative from the equations in order to determine the components of the velocity on the axes. It is in the process of derivation that students make certain mistakes in finding the derivatives of equations in the conditions of two problems. It is in this place that the "matryoshka" method can be used in both cases. In this case, we write down the equations in the following form: The equation of the condition of the first problem is as follows $(f(\varphi(t))^2$, and we can write the equation in the second problem in the form $f(\varphi(t))$. After writing it down in this form, if we apply the matryoshka method to the first $F = (f(\varphi(t))^n$ function, it will be seen that we must first derive the derivative from the outermost shell, i.e. the degree. We will have a view on $F' = 2(f(\varphi))^{(n-1)} f'_\varphi \times \varphi'_t$. From the first equation

$$\dot{x} = v_x = a \times 2\cos 5t \times (-\sin 5t) \times 5 = -5sin10t \quad (15)$$

$$\dot{y} = v_y = a \times 2\sin 5t \times \cos 5t \times 5 = 5sin10t \quad (16)$$

we will get the results, we will move to the general speed:

$$v = \sqrt{{v_x}^2 + {v_y}^2} = 5\sqrt{2}\,sin10t \qquad (17)$$

By integrating the speed over time, we establish the law of movement along the trajectory:

$$s = -\frac{\sqrt{2}}{2}\cos(10t) \quad (18)$$

it follows that.

We also use the "matryoshka" method to find the components of the speed on the axes by deriving the time derivative from the equations in the second problem. That is, from the function in the form of $f(\varphi(t))$ each parenthesis is opened and the derivative is obtained from the function in the form of the previous function. It's like opening matryoshka shells. As a result $F' = f'_\varphi \times \varphi'_t$

$$\dot{x} = v_x = -\sin(5t^2) \times 10t \qquad (19)$$

$$\dot{y} = v_y = \cos(5t^2) \times 10 \qquad (20)$$

Let's go to the general speed $v = \sqrt{{v_x}^2 + {v_y}^2} = 10\sqrt{2}t$ (21)
is formed.

By integrating the speed over time, we establish the law of movement along the trajectory: $s = 5\sqrt{2}t^2$ (22)

we get the equation.

In many cases, students hesitate when deriving the equations from the above two problems. Explanation in the "Matryoshka" method increases the mastery rate.Formulas need to be rewritten! It was incomprehensible.

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